PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G05B 23/02, 17/02

A1

(11) International Publication Number: **WO 00/41050**

(43) International Publication Date: 13 July 2000 (13.07.00)

(21) International Application Number: PCT/EP99/07793

(22) International Filing Date: 5 October 1999 (05.10.99)

(30) Priority Data:
MI98A002873 31 December 1998 (31.12.98) IT

(71) Applicant *(for all designated States except US)*: ABB RESEARCH LTD [IT/IT]; Affolternstrasse 44, P.O. Box 8131, CH–8050 Zurich (CH).

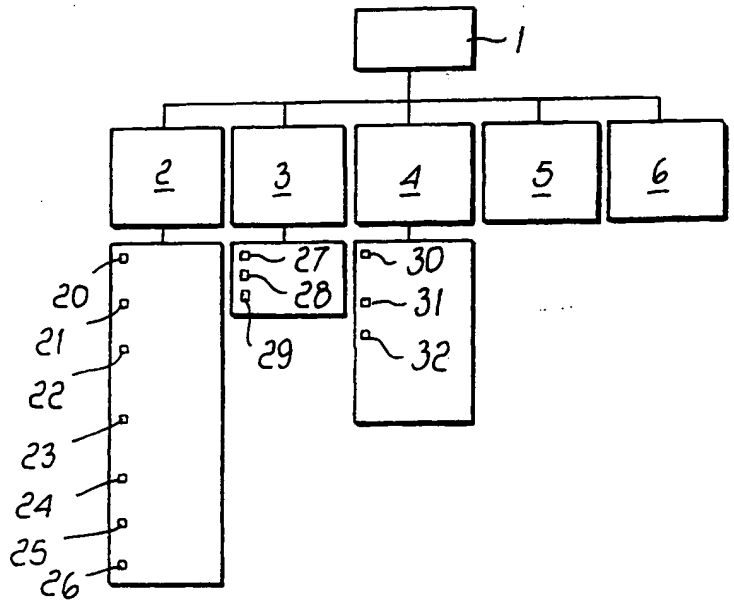
(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: CEINER, Guido [IT/IT]; Via Ebro, 11, I–20141 Milano (IT). DANIELI, Massimo [IT/IT]; Via S. Marco, 84, I–37138 Verona (IT). FERRARINI, Luca [IT/IT]; Via Padre Beschi, 36, I–46043 Castiglione Delle Stiviere (IT). MAFFEZZONI, Claudio [IT/IT]; Via Tofane, 6, I–26100 Cremona (IT). CATALDO, Andrea [IT/IT]; Via Mazzini, 12, I–20093 Cologno Monzese (IT).

(74) Agent: GIAVARINI, Francesco; ABB Ricerca S.p.A., Viale Edison, 50, I–20099 Sesto San Giovanni (IT).

(81) Designated States: BR, CA, CN, IN, JP, KR, PL, US, Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: TESTING DEVICE FOR INDUSTRIAL CONTROL SYSTEMS



(57) Abstract

A testing device for industrial control systems, comprising: editing means (2) which allow to compose a software test bench for a control system of an industrial plant; storage means (4), suitable to provide the editing interface means with predefined models which describe a physical process being controlled; modeling means (3), suitable to guide and facilitate the testing engineer in testing standard control loops; simulation means (5) which comprise a simulation engine suitable to process the models generated by the editing interface means; and hardware means which are suitable to interface the testing system with a control system to be tested.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

TESTING DEVICE FOR INDUSTRIAL CONTROL SYSTEMS

DESCRIPTION

The present invention relates to a bench-testing device for industrial control systems. More particularly, the present invention relates to a testing device to be used during the factory-testing of industrial control systems.

It is known that the configuration software of industrial control systems (control and interlock logic systems, graphic pages, structures for analog regulation, startup and placing the plant in safe mode) usually uses a testing panel of the hardware type. This panel, after being set up, is physically connected to the input and output boards of the control system to be tested and allows closing the control and regulation loops to be tested.

The hardware panel is generally constituted by:

-- potentiometers, for replicating the analog signals (e.g. 4-20 mA signals) from the plant (for example level, pressure, position, flow-rate, temperature transducers);

-- a simulator for simulating the heat probes and thermocouples connected to the control system;

-- switches for replicating the digital signals (e.g. 0-24 V), for example limit switches on valve positioners, status indicators from users such as pumps and motors, pressure switches, level switches and the like;

-- amperometers for replicating the actions of the analog actuators provided in the plant (for example valve regulations, motor rpm-rate adjustments and the like);

-- indicators in order to replicate the actions of the digital actuators provided in the plant (for example stop and start actuators for pumps, for closing two-state valves and the like);

-- terminal devices for interfacing with the control system

-- power supplies to be used for all the components that require a power

supply.

Accordingly, each one of the devices provided on the hardware panel is assigned with a specific function among those provided in the plant portion to be tested (valve, switch, transducer, actuator, etcetera). Each one of these devices is then connected, by means of dedicated cables, to the specific channel of a given acquisition (input) or control (output) board of the control system, so as to close the control loops provided by the designer of the control system.

In this way the control system is tested before physically implementing it in the field.

The operators involved in the control system testing work check on the hardware panel that the commands issued by the controller are correct (lighting of lamps and indication of amperometers) and provide the controller with the appropriate signals which, during normal operation, would arrive from the plant (potentiometers and switches).

In some cases, and for particular boundary conditions, preference is given to the use of software programs instead of the hardware panel. Such programs must be written in the specific language of the particular control system platform and must be executed by the controller during testing.

The purpose of these programs is the same as for the hardware panel. They are aimed to having, during testing, an instrument, which can provide the controller with the signals normally provided by the plant (when the controller is implemented in the plant) and receive from the controller the commands that are normally sent to the plant (plant control commands).

The hardware panels commonly used are characterized by the following drawbacks.

First of all, in order to have a panel, which exactly reproduces the plant portion to be tested, it is necessary for the devices included therein to fully correspond, in terms of number and type, to the instruments connected to the control system

and contained in the same plant section. This entails an onerous preparation of the hardware panel.

Moreover, the connection between the control system to be tested and the conventional testing panel is provided by means of electrical cables. This entails the need for considerable time in order to provide and check the connection of any input and/or output channel of the control system to the various elements of said panel, in addition to requiring bulky wiring.

Another drawback is due the fact that the testing of control systems is always performed by individual plant portions for complexity reasons. Any time the testing of a new plant portion begins it is necessary to reassemble and reconnect the hardware panel, which is accordingly scarcely flexible in relation to the continuous modifications that are required when testing a plurality of plant sections in succession.

Errors are unavoidably made during the preparation of the testing panel and during its subsequent connection to the control system and are added to the errors already present in the configuration software of the controller. The presence of these errors increases the complexity of system testing and reduces its effectiveness and efficiency.

One of the main problems encountered during the testing of control systems is the fact that, once the presence of an error has been detected, it is necessary to determine whether the error is due to a physical (hardware) problem or to a configuration (software) problem. Using an hardware testing panel considerably increases the amount of electronic components (potentiometers, switches, lamps) and cables (cable discontinuity problems, poorly executed soldering between cables and their terminals) that can be affected by defects and in any case constitute a weak link in control system testing.

Moreover, providing inputs to the control system by means of hardware (for example a potentiometer set to a given value) is neither easy nor stable, since

the measure can oscillate in the neighborhood of the intended value. This fact considerably complicates testing operations and reduces the consequent level of precision and reliability.

It often occurs that the testing engineers must reproduce certain very complex operating sequences. The conventional testing bench does not facilitate the execution of all the necessary operations. For example, the action of stopping a pump, with the consequent closure of the intake and delivery valves and with an interlocking action with respect to other plant portions, results quite complicated. In fact, it entails that one or more operators must operate various devices of the panel and constantly monitor both the indications of the panel and the information from the control system.

Also the use of software programs, written specifically in the proprietary language of the control platform used in each instance, is not free from drawbacks.

First of all, as mentioned, these testing programs must be written in the particular language of the specific control system used for a certain plant. This of course entails the need for the programmer to acquire specific skills regarding the control being used.

Moreover, this drawback is worsened by the fact that when the programmer changes plant he often finds himself using a different control system having a new programming language and therefore the previously written testing software can no longer be used for the new situation.

The need to write ad-hoc software programs in the specific language of the control system, and especially software programs which very likely will have to be written in the presence of a different type of plant, entails considerable efforts and costs.

Additionally, the functional correctness of software programs for testing plant control systems is difficult to be checked promptly.

Therefore, the aim of the present invention is to provide a testing device, for industrial control systems, which allows eliminating conventional hardware test benches and control system-specific software programs. It must allow, at the same, editing a model of the components of the plant to be tested and therefore perform its factory testing.

Within the scope of this aim, an object of the present invention is to provide a testing device, for industrial control systems, which allows preparing, in an assisted and reusable manner, a software bench. The software bench is aimed to test industrial control systems and allows defining the structure of the plant portion being controlled independently of the hardware/software platform used.

Another object of the present invention is to provide a testing device, for industrial control systems, which allows reducing the time and cost entailed by factory testing, which is compulsory before the field installation of an industrial control system.

Another object of the present invention is to provide a testing device, for industrial control systems, which allows eliminating the operations for wiring and assembly a conventional hardware panel to the control system to be tested, and therefore the costs arising from the construction of said hardware panel.

Another object of the present invention is to provide a testing device for industrial control systems which allows reusing the software bench prepared with the device according to the invention, accordingly offering high flexibility in use.

Another object of the present invention is to provide a testing device for industrial control systems, which allows to evaluating much more complex control logic systems than allowed by a conventional testing panel.

Thus the present invention provides a testing device for industrial control systems, comprising:

- editing means which allow to compose a software test bench for a control

system of an industrial plant; and

- storage means, suitable to provide said editing interface means with predefined models which describe a physical process being controlled; and
- modeling means, suitable to facilitate the composition a portion of said test bench related to the testing of said adjustment loops; and
- simulation means which comprise a simulation engine suitable to process the models generated by said editing interface means; and
- hardware means suitable to interface said testing system with a control system to be tested.

Further characteristics and advantages of the present invention will become apparent from the following detailed description of preferred but not exclusive embodiments of the device according to the invention, illustrated only by way of non-limitative example in the accompanying drawings, wherein:

Figure 1 is a block diagram of the testing device according to the present invention; and

Figure 2 is a block diagram of the use of the testing device according to the invention, connected to a plant control system.

With reference to the above figures, the testing device according to the present invention consists of a device which is suitable to create a model of the components of an industrial plant, which exchanges information with a control system (prepared for the industrial plant). The testing device according to the present invention is also suitable to execute the resulting model in order to directly factory-test said control system.

The testing device according to the invention, designated by the reference numeral 1, comprises, as shown in Figure 1, editing means 2, which allow composing a software test bench by assembling various models taken from storage means 4. By way of said editing means 2, it is also possible to connect all the input and output signals exchanged between the control system and the

plant, rerouting them onto the bus of the control system, with the inputs and the outputs of the models used.

Preferably, the editing interface means allow performing the following functions:

-- preparing a new plant model (20);

-- setting the parameters of the plant model (21);

-- connecting a plant model and the control system 10 of said plant (22);

-- managing the conditioning and forcing of the signals (23);

-- deleting signals and connections (24);

-- saving the plant model thus defined (25);

-- printing the model (26).

The testing device according to the invention is further provided with modeling means 3, which provide functions suitable to guide and facilitate the testing engineer in synthesizing a simplified model to be used for testing particular control loops. If the loops to be tested are standard (for example pump control, simple adjustment loops, etcetera), modeling means allow advantageously the testing engineer to simply input few parameters that characterize the individual loop and to compose semi-automatically the software test bench part related to the testing of said loops. The modeling means 3 therefore comprise functions 27 for individual loops, functions 28 for cascaded loops and functions 29 for modeling driving devices such as valves or motors or the like.

The testing device according to the invention further comprises, as mentioned, storage means 4 which are meant to provide the testing engineer with a plurality of pre-wired models for closing the loops to be tested.

The storage means 4 can be represented, for example, by libraries of plant models. These models allow, for example, emulating plant responses. For example, when testing the drive of a pump, time delays might be used to obtain plant response emulation. The models contained in the storage means 4 are

therefore constituted by input-output functions with 1-2 poles, or in algebraic relationships, or by pure delays, so as to give the feedback signal from the plant a minimum of dynamic range.

The models available can be, for example, regulation and/or on/off valves 30, pumps and/or motors 31, analog indications (for example levels, flow-rates, positions) and/or digital indications (for example pressure switches, level switches, limit switches) 32. The device according to the invention further includes a simulation engine 5, which is meant to process the simplified models. It constitutes the feedback to the control system 10 and is connected to the inputs and outputs of the control system, appropriately re-routed on the bus 12 of the controller 13.

The simulation engine 5 accordingly receives in input the structure of the plant components, produced by the testing engineer by using the models of the storage means 4, made available within the testing device 1.

Finally, the hardware means 6, suitable to interface the testing device to a specific industrial control system 10, are meant to exchange the input and output signals of the control system 10 rerouted on the control bus 12 of the control system 10. Said means 6 must be designed specifically for the control bus 12 to which the test bench provided by the device according to the invention connects and specifically for the data exchange protocol used by the specific control system 10 that is used.

In Figure 2, the reference numeral 10 designates the control system of a plant, which is generally designated by the reference numeral 11. The reference numeral 12 designates the control bus, which carries signals to controllers 13 and to I/O cards 14 of the control system 10. The control bus is connected to interface means 6 which allow to connect the testing device 1 to the control system 10.

In this case, the testing device 1 shown in Figure 2 is understood to include the

editing interface means 2 and the means 3-5 described hereafter in detail and shown in Figure 1.

The testing device according to the invention therefore can be, in practice, implemented by means of a computerized system, which can be connected to the control bus 12 of the industrial control system 10 through the interface means 6. The monitor, the keyboard and the mouse of the computerized constitute the tools that can help the basic editing and modeling functions available. The testing engineer receives via monitor all the indications related to the signals sent by the testing device according to the invention (commands to pumps, regulator control actions, etcetera). Monitoring of the feedback signals, that the software test bench supplies to the control system 10 through the interface means 6, can be performed.

This is achieved by means of the simulation engine 5, which runs on the electronic computer and is capable of executing the model defined by the testing engineer.

In practice it has been observed that the testing device according to the invention fully achieves the intended aim and objects, since it allows to eliminate the hardware test bench and software test benches designed specifically for a particular control system to be tested.

The test bench created by the testing device according to the invention allows high sensitivity in use and a high level of simplicity for the testing engineer.

The test benches thus created can also be easily used for different control systems, since they are not dependent on a specific programming language.

The testing device thus conceived is susceptible of numerous modifications and variations, all of which are within the scope of the inventive concept; all the details may also be replaced with other technically equivalent elements.

CLAIMS

1. A testing device for industrial control systems, comprising:
   - editing means which allow to compose a software test bench for a control system of an industrial plant; and
   - storage means, suitable to provide said editing interface means with predefined models which describe a physical process being controlled; and
   - modeling means, suitable to facilitate the composition of a portion of said test bench related to the testing of said control loops; and
   - simulation means which comprise a simulation engine suitable to process the models generated by said editing interface means; and
   - hardware means suitable to interface said testing system with a control system to be tested.

2. The testing device according to claim 1, characterized in that said editing means provide the following functions:
   - preparing a new plant model;
   - setting the parameters of the plant model;
   - connecting a plant model and said control system;
   - managing the conditioning and forcing of signals of said control system;
   - deleting signals and connections;
   - saving said plant model thus created;
   - printing said model.

3. The testing device according to claim 1, characterized in that said modeling means provide the following functions:
   - single loop modeling;
   -- cascade loop modeling;
   -- modeling of driving device commands.

4. The testing device according to claim 1, characterized in that said hardware

means exchange input and output signals of said control system re-routed on a control bus of said control system.

5. The testing device according to claim 1, characterized in that said storage means comprise one or more libraries of models constituted by input-output functions, algebraic relations, pure delays and the like.

6. The testing device according to claim 1, characterized in that it provides by said editing means, through said model library means and said modeling means, feedback signals to said control system, by means of said hardware means, in response to commands given by said control system.

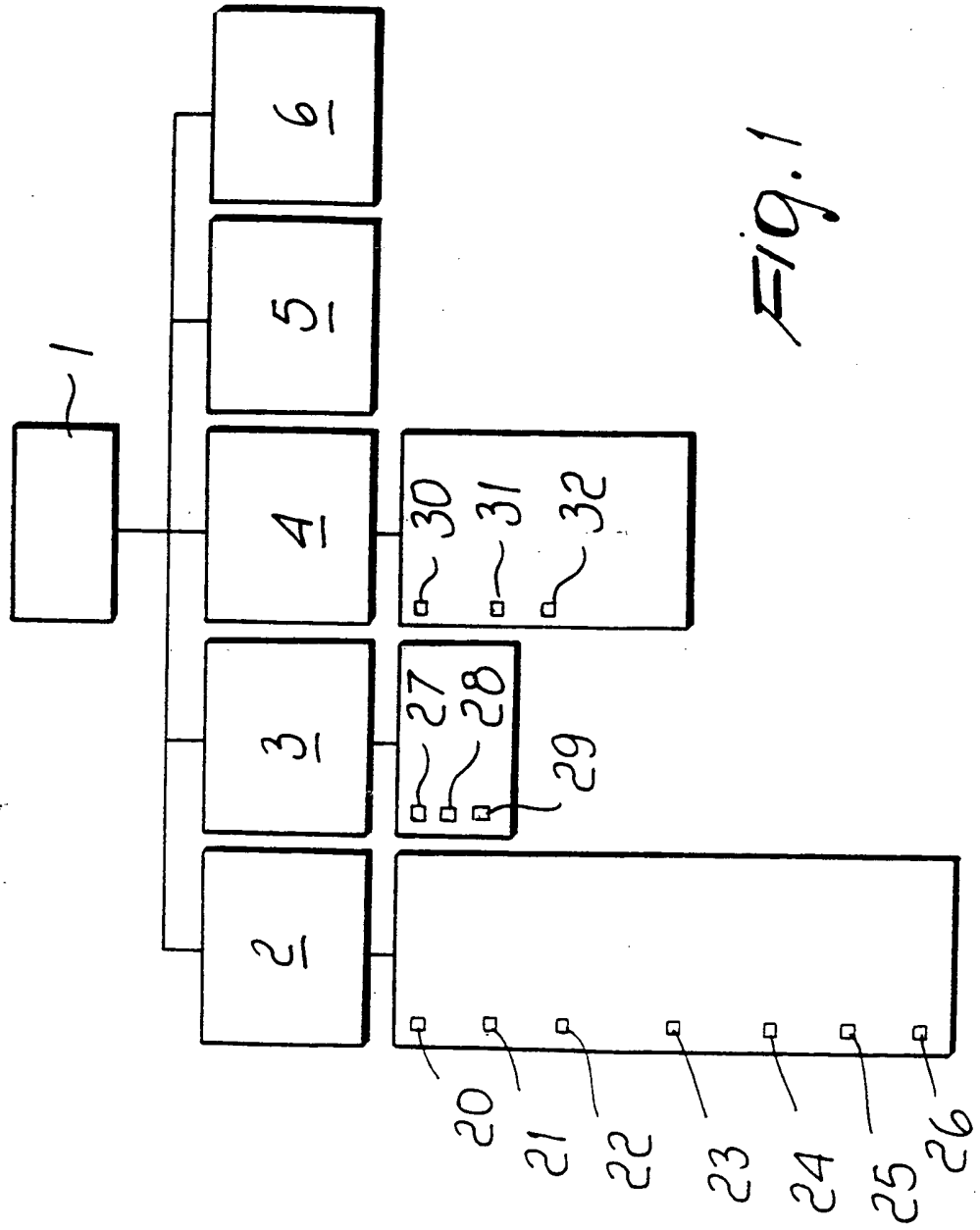


Fig. 1

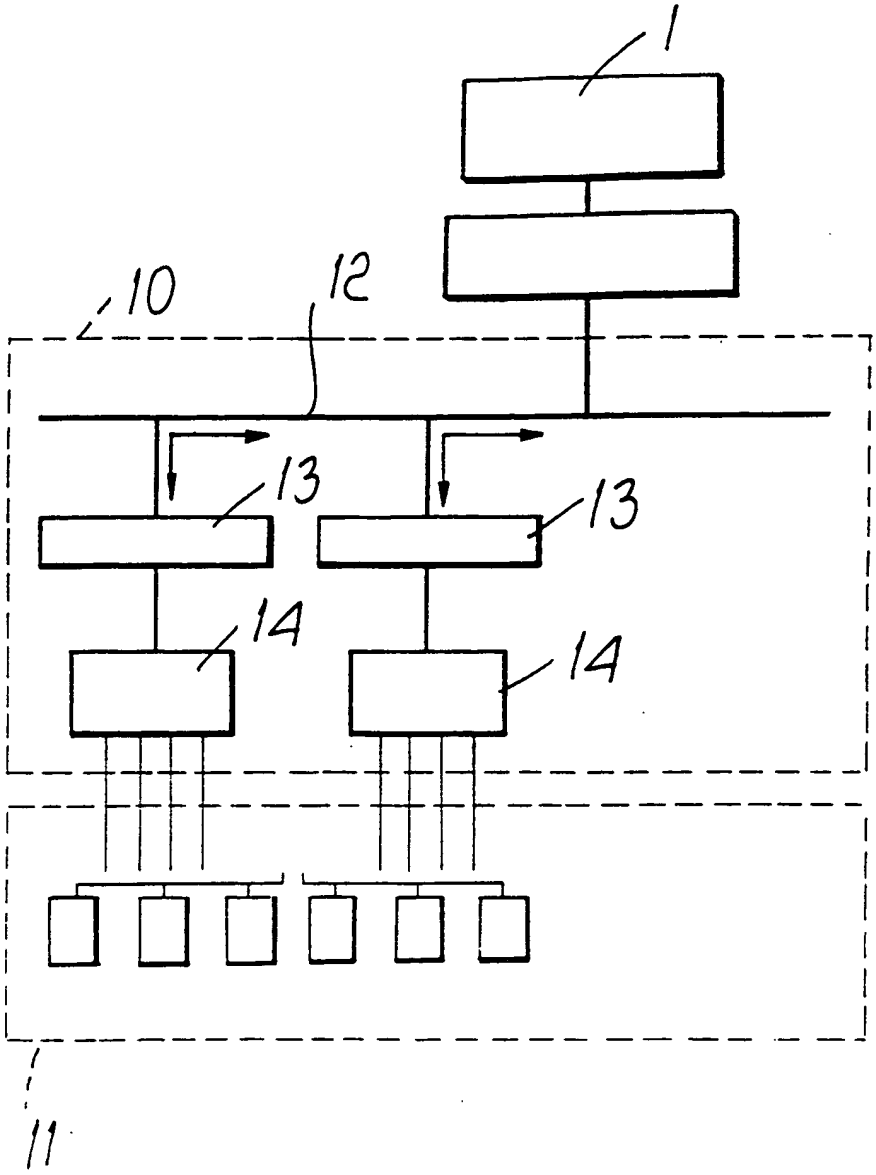


FIG. 2

INTERNATIONAL SEARCH REPORT

Interm ıal Application No
PCT/EP 99/07793

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G05B23/02 G05B17/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 758 123 A (OGASAWARA ATSUSHI ET AL) 26 May 1998 (1998-05-26) the whole document ---	1
A	US 5 371 851 A (GREENSETH WILLIAM A ET AL) 6 December 1994 (1994-12-06) column 67, line 18 -column 71, line 36 ---	1
A	EP 0 283 382 A (SPIE TRINDEL) 21 September 1988 (1988-09-21) the whole document ---	1
A	GB 2 293 886 A (S3 RESEARCH & DEV LIMITED) 10 April 1996 (1996-04-10) the whole document ---	1
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 February 2000	24 02. 2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Kelperis, K

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Inte ional Application No
PCT/EP 99/07793

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 663 900 A (BHANDARI NARPAT ET AL) 2 September 1997 (1997-09-02) the whole document	1
A	DE 195 23 483 A (DAIMLER BENZ AG) 2 January 1997 (1997-01-02) the whole document	1
A	US 5 812 394 A (LEWIS ROBERT W ET AL) 22 September 1998 (1998-09-22) the whole document	1
A	R.ISERMANN ET AL : "HARDWARE-IN-THE-LOOP SIMULATION FOR THE DESIGN AND TESTING OF ENGINE-CONTROL SYSTEMSW " PROCEEDINGS OF THE 5TH IFAC WORKSHOP ALGORITHMS AND ARCHITECTURES FORREAL TIME CONTROL,15 April 1998 (1998-04-15), pages 1-10, XP000870020 MEXICO	1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte. .onal Application No
PCT/EP 99/07793

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5758123 A	26-05-1998	JP 7282103 A	27-10-1995
		JP 7287720 A	31-10-1995
		JP 7287721 A	31-10-1995
		JP 7296020 A	10-11-1995
		JP 8054907 A	27-02-1996
		US 5991533 A	23-11-1999
US 5371851 A	06-12-1994	JP 2627458 B	09-07-1997
		JP 3073069 A	28-03-1991
EP 0283382 A	21-09-1988	FR 2612309 A	16-09-1988
GB 2293886 A	10-04-1996	BE 1007163 A	11-04-1995
US 5663900 A	02-09-1997	NONE	
DE 19523483 A	02-01-1997	FR 2736151 A	03-01-1997
		GB 2303231 A,B	12-02-1997
US 5812394 A	22-09-1998	NONE	